ATDEV-6 452(12 Apr 61) 1st Ind
SUBJECT: Report of Test, Project Nr AVN 2161, "Evaluation of Automatic Flight Control System AN/ASW-12(V) in an RL-23D Airplane"

Headquarters, United States Continental Army Command, Fort Monroe, Virginia, 9 May 1961

TO: Chief of Research and Development, Department of the Army, Washington 25, D. C.

This headquarters approves the conclusions and recommendations of Report of Test, Project Nr AVN 2161, restated as follows:

a. Conclusions:

(1) The AN/ASW-12(V) Automatic Flight Control System will be suitable for use in RL-23D Airplanes when deficiencies and shortcomings listed in subparagraph 4g of the report are corrected.

(2) The AN/ASW-12(V) Automatic Flight Control System appears acceptable for use in other Army fixed-wing aircraft.

(3) The universal aspects of the AN/ASW-12(V) should be thoroughly tested and considered before type classification.

b. Recommendation: That type classification of the AN/ASW-12(V) as Standard A be delayed pending completion of service tests in the AO-1 and H-21.

FOR THE COMMANDER:

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UNITED STATES ARMY AVIATION BOARD
Fort Rucker, Alabama

ATBG-SEC AVN 2161 12 APR 1961

SUBJECT: Report of Test, Project Nr AVN 2161, "Evaluation of Automatic Flight Control System AN/ASW-12(V) in an RL-23D Airplane"

TO: Commanding General
United States Continental Army Command
ATTN: ATDEV
Fort Monroe, Virginia

1 AUTHORITY.

a. Directive. Letter, ATDEV-6, Headquarters, USCONARC, 5 January 1961, subject. "Evaluation of AN/ASW-12 in RL-23D Airplane."

b. Purpose.

(1) To conduct an evaluation of the AN/ASW-12 Automatic Flight Control System (AFCS) installed in the RL-23D to determine the suitability of the equipment for use in the RL-23D.

(2) To comment, on the basis of the evaluation, on the general acceptability of the AN/ASW-12 for use in Army fixed-wing aircraft.

2. BACKGROUND.

a. The Statement of Requirement in the USCONARC-approved military characteristics (reference 8b) for a universal autopilot (Automatic Flight Control System) states that the equipment shall be. "A simple, reliable, lightweight universal autopilot system that will be capable of being coupled with existing navigation, guidance, and landing equipment of the time period. It will be capable of providing stabilization of up to five references by adding or removing plug-in-type

modules. This equipment will be suitable for installation in Army Aerial vehicles when required for successful accomplishment of the primary mission. When required in an aerial vehicle, it will be included in Table E of the model design specifications for this vehicle. (LR) CDOG sub-paragraph is 533e(11)."

b. The Sperry Phoenix Company designed and developed the AN/ASW-12 AFCS under contract Nr DA-36-039SC-750-40. A service test model has been installed in an Aviation Board H-21 helicopter and is currently undergoing service test at Fort Rucker.

c. The US Army Signal Research and Development Laboratory conducted the engineering test of the AN/ASW-12(V) installed in an RL-23D. The equipment installed in the engineering test airplane was received by this Board on 15 December 1960; a maintenance package was provided.

3. DESCRIPTION OF MATERIEL. The AN/ASW-12(V) AFCS is manufactured by the Sperry Phoenix Company, Phoenix, Arizona. The system is designed so that calibration of the system to the type of airplane is performed at the factory, and no further adjustments should be required in the field. The AFCS consists of physically separated but electrically interconnected units. These units are mounted in the airplane either at the position of required operation or, when the unit needs no specific operational location, at any position where space is available. The controls requiring in-flight use are located in positions accessible to the pilot.

a. The AFCS is an attitude-stabilization and flight-path-guidance system designed to be used in airplanes and helicopters, manned or drone. In the airplane installation, there are three channels of control: pitch, roll, and yaw.

(1) Airplane attitude stabilization is accomplished by electrical signals generated in gyroscopes which sense deviation from established reference attitudes. The signals from the gyroscopes are amplified and fed to servomotors which produce corrective motion of the airplane control surfaces. Commands may be imposed by means of a flight controller.

(2) The AFCS is designed to be coupled to various navigational and approach systems--very-high-frequency omnidirectional radio range (VOR), a Doppler navigation system, instrument landing system (ILS)--to provide automatic flight path control.

(3) The AFCS is designed to provide automatic altitude control from signals from an integral barometric sensor, a radar altimeter, or the glide-slope receiver.

b. The AFCS has two basic modes of operation - synchronization and stabilization.

(1) In the synchronization mode, power is on, but the AFCS is not engaged. All error signals transmitted from the vertical gyro, compass system, and other sensors are nulled to provide a transient-free engagement of the system.

(2) In the stabilization mode (AFCS engaged), deviation error signals are used to apply corrective forces to the control surfaces of the airplane.

4. TESTS.

a. Physical Characteristics.

(1) Size and Weight. The weight and volume of the AFCS, as reported by the manufacturer, are 40.3 pounds and 0.81 cubic foot (electrical wiring, cable, and brackets not included). The installed weight could not be accurately determined; however, the installed weight is estimated to be 65 to 70 pounds.

(2) Electrical Requirements.

| 115 VAC A Phase (Amps) | 115 VAC C Phase (Amps) | 27.5 VAC (Amps) | Condition |
|---|---|---|---|
| .46 | .47 | 2.0 | Initial starting |
| .42 | .27 | 1.2 | After 1.5 minutes |
| .42 | .10 | 1.35 | Standby conditions |
| .42 | .10 | 2.65 | ASW-12 engaged |
| .42 | .10 | 4.15 | One-axis hardover |
| .42 | .10 | 6.15 | Two-axis hardover |
| .42 | .10 | 8.35 | Three-axis hardover |

(3) Complexity. The AFCS was less complex than other autopilots previously tested by this Board. Fewer components were required since some components performed two or more functions.

b. Operational Characteristics. The RL-23D with the AN/ASW-12 installed was flown, both day and night, 139 hours under VFR and IFR conditions.

(1) Accuracy and Reliability.

(a) In-Flight Engagement.

1. The AFCS was engaged during climbs, dives, turns, and level flight. A transient-free, smooth engagement resulted with the autopilot maintaining the airplane in the established pitch attitude at the time of engagement, and maintaining, or returning it smoothly to, a wing-level condition.

2. Coupling of the AFCS to the AN/ASN-13 magnetic compass for heading reference resulted in small but constant movement of the rudder pedals because of vibration of the AN/ASW-13 in its shock mounting on the airplane instrument panel. The rudder movement was so small that it had no noticeable affect on the flight path of the airplane.

(b) Command Operation (Flight Controller). The airplane was maneuvered utilizing the TURN knob, the ROLL TRIM control, and the BEEP switch. The AFCS provided immediate, smooth response, and controlled the airplane within calibrated limits except during entry into turns. Coordinated entry into turns resulted as long as the airplane was properly trimmed with the normal rudder-trim control. Entry into turns when the rudder was out of trim resulted in an initial yaw in the opposite direction of the turn. Coordinated turns up to 45 degrees of bank and maximum pitch changes within the performance limits of the airplane (approximately six degrees per second) were achieved consistently.

(c) Automatic ILS Approaches. Forty ILS approaches were made at eight airfields. The AFCS controlled the airplane satisfactorily on the localizer course and the glide path during the majority of these approaches. Some approaches resulted in erratic tracking of the localizer course until the VERTICAL mode switch was placed in the APPROACH (glide-slope) position, which decreased from 25 degrees to 10 degrees the authority of the system to bank the airplane and increased sensitivity to off-course signals. Erratic tracking of the localizer course was also experienced when flying the ILS back course outbound from the localizer transmitter until the airplane was 10 to 15 miles from the airfield. In both cases, erratic tracking of the localizer course was eliminated by placing the VERTICAL mode switch in the APPROACH position.

(d) Automatic VOR.

1. Numerous cross-country flights were made with the AFCS automatically controlling the airplane in the VOR mode. Control was smooth and accurate, and the AFCS consistently directed the airplane to, over, and from an OMNI station on the selected radial. Accurate VOR approaches at approach speeds (approximately 110 knots)

were made in cross winds of up to 40 knots while the AFCS maintained drift corrections up to 25 degrees.

2. Using the IN-14 VOR indicator for the HEADING SELECT mode limits the use of the VOR to which the AFCS is coupled.

3. Interception of VOR courses at large angles is impractical because of the limited bank authority (10 degrees) in the VOR mode.

(e) Heading Selector. The ability of the AFCS to seek and maintain a selected heading was found to be satisfactory at all times.

(f) Barometric Altitude Control.

1. The AFCS was found to be capable of maintaining altitude within 25 feet in smooth air at various density altitudes tested (from sea level to 20,000 feet) and in turns up to standard rate. In light turbulence, deviations did not exceed 60 feet.

2. Engagements of the barometric altitude control during climbs usually resulted in altitude stabilization within ± 25 feet of the engaged altitude. However, a deviation of minus 200 feet from the engaged altitude occasionally occurred.

(2) Ease of Operation and Adequacy of Operating Ranges. The controls and switches on the AFCS were simple and easy to operate. Preflight and in-flight operations were easily accomplished. The operating limits in pitch and bank were adequate for all regimes of flight except as previously noted in the RL-23D. These limits were as follows:

(a) Pitch.

1. Up - 25 degrees.

2. Down - 13 degrees.

(b) Bank.

1. Command operation 45 degrees.

2. Heading select and localizer - 25 degrees.

3. VOR and ILS localizer after glide-slope interception - 10 degrees.

(3) Performance Under Single-Engine Conditions.

(a) Performance of the AFCS under single-engine conditions was satisfactory in all modes of operation. The pilot, however, must manually trim out all rudder pressure because no automatic rudder trim is provided.

(b) In the event of a sudden and complete engine failure, the AFCS was capable of maintaining the airplane on a heading only when operating in the basic stabilization mode. In this mode, it effected rudder displacement in the proper direction to maintain the airplane on a heading. When using the VOR, ILS, or HEADING SELECT modes, the AFCS effected rudder displacement in the direction of the power loss; this rudder application is opposite to that required to maintain the desired heading. (See paragraph g(2)(d) below.)

(4) Suitability of Controls and Malfunction-Warning Device. Controls and malfunction warning devices were suitable except as noted below:

(a) Flight Controller.

1. The DETENT position of the TURN knob was too sensitive, very small lateral pressures on the TURN knob caused the lateral function to become disengaged.

2. The word "turn" and the right and left turn arrows on the TURN knob are printed on the after side of the knob. Placing the word "turn" and the arrows on the forward side of the knob would orient them with respect to the movement of the airplane.

3. The electrical wiring from the airplane's power source and sensor devices to the flight controller interfered with the freedom of movement of the pilot's right leg and with the installation of the airplane's control lock.

(b) Navigational Coupler. The pilot's view of the navigational coupler control panel was obstructed by the airplane control column and the flight controller.

(c) AFCS Light Indicators. In the RL-23D installation, the standby light had a dual purpose- to indicate when the AFCS was ready for engagement and to indicate that a power failure, either a.c or d.c., had occurred. The pilot had to press the power failure test switch located adjacent to the light, to determine which function the light indicated. No lights were provided to indicate whether the modes of operation on the navigational coupler were functioning.

(d) Adequacy of the Fail-Safe Features.

1. The shear pin in the pitch-axis actuator assembly, which joins the output drive gear to the drive shaft, was unsatisfactory. This pin is designed to enable the pilot manually to overcome any binding or jamming of the gears inside the actuator assembly which would freeze the control surface of the airplane. Six pins were broken during the evaluation, and, in each case, the shear pin was not sheared in the performance of its designated purpose.

2. A feature to limit abrupt airplane pitch changes was not provided to avoid extreme attitude changes encountered in turbulent air.

(5) Suitability of Illumination. Illumination of the AFCS controls was suitable for night operations.

(6) Suitability of the Equipment During Local and Cross-Country Flights Under Actual or Simulated Instrument Conditions. Numerous local and cross country flights were flown under actual and

simulated instrument conditions. The automatic coupling to VOR and ILS and the automatic altitude control feature made flying under actual instrument conditions more accurate and substantially reduced pilot fatigue.

(7) Autopilot Action During Large Power Changes and Rapid Acceleration. Control of the airplane by the AFCS during large power changes and rapid acceleration and deceleration was accurate and smooth at all times.

c. Tactical Suitability.

(1) Ruggedness. The AFCS appeared to be rugged except for the shear pin in the pitch actuator assembly (see paragraph b(4)(d) above).

(2) Suitability of the Equipment To Operate with Tactical Navigational Devices.

(a) No provision existed in this installation for automatic coupling of the AFCS to automatic-direction-finding (ADF) and FM equipment. (The manufacturer indicates that an ADF capability can be added.) However, using the HEADING SELECT mode permitted easier and more accurate ADF tracking.

(b) Use of the HEADING SELECT mode for lateral control and the BEEP switch for glide-path control facilitated the execution of precision-type ground-controlled approaches with a minimum of pilot effort.

(3) The Degree to Which This Equipment Enhances the Capability of the Pilot To Operate the Airplane. The AFCS substantially enhanced the capability of the pilot to operate the airplane. The reduction in pilot effort required to control the airplane permitted a better division of attention for outside observation, scan of all instruments, study of maps and charts, and operation of radios. Use of the AFCS resulted in more accurate navigation, in-flight planning, and recording of flight information or instructions. The AFCS would materially reduce the need for a copilot in those airplanes for which a copilot is required for instrument flight.

d. Personnel.

(1) After a brief preflight orientation and two hours of in-flight instruction, aviators were able to operate the system with ease.

(2) Navigation Equipment Electronic Repairman, MOS 284, required 40 hours of on-the job training (basic operation of the system, trouble shooting, replacement of sub-assemblies, and minor adjust ments) in order to maintain this equipment at organizational and field maintenance levels.

(3) The operating and maintenance instructions were adequate for the evaluation.

e. Maintenance.

(1) The maintenance package was adequate for the evaluation, however, a detailed report of the maintenance package for the AN/ASW-12(V) will be included in the service test of the system installed in an H-21 helicopter.

(2) The following corrective maintenance was performed:

| Malfunction | Corrective Action | Man-Hours |
|---|---|---|
| Sheared six pins in pitch axis actuator assembly. | Replaced pins. | 6 |
| Worn shear pin in YAW drum and bracket assy. | Replaced pin. | 1 |
| Erratic operation in YAW axis. | Replaced clutch in YAW actuator. | 7 |
| ILS approaches to one side. | Attached ground strap between nav. coupler and ground. | 0.5 |

| Malfunction | Corrective Action | Man-Hours |
|---|---|---|
| Light too dim in flight controller. | Adjusted lighting resistor. | 0.5 |
| Erratic operation of pitch trim tab servo. | Adjusted limit switches and clutch tension in trim tab servo. | 6 |
| Turn knob leaves detent too easily. | Adjusted micro switches and detent spring of flight controller. | 7 |

(3) No unduly difficult or time-consuming operation or design deficiencies prejudicial to ease of maintenance were noted during the test period.

(4) Organizational tools are considered adequate to perform organizational maintenance, and no special tools or special test equipment are required.

f. Comparison with Military Characteristics.

(1) The AFCS as installed in the RL-23D does not meet the military characteristics (reference 8b) specified for fixed-wing aircraft in the following areas:

(a) The equipment does not provide the means for coupling to:

1. Radio and radar data link receiver.

2. Terrain and air traffic viewer.

3. Collision avoidance sensor

4. Tactical navigation system (FM and ADF) of the period.

(b) No provision exists for automatic disengagement of the altitude control prior to stall of the aircraft.

(c) The equipment exceeds the installed weight and volume limits by 20 to 25 pounds and approximately .15 cubic foot, respectively.

(d) The equipment requires a warm-up period 30 seconds longer than that specified.

(2) Whether the AFCS installed in the RL-23D meets the approved military characteristics specified for fixed-wing aircraft in the following areas could not be determined:

(a) The equipment in fixed-wing installations shall hold a command angle of bank (coordinated flight) within $\pm 1^{\circ}$ up to a bank of $30^{\circ}$ in level flight, climb, or dive. (This Board is not equipped to measure angles of bank with the degree of accuracy required by these MC's.)

(b) The equipment shall hold a command pitch attitude within $\pm 1^{\circ}$ up to $\pm 7.25^{\circ}$. (See note in parenthesis above.)

(3) The AFCS does meet all other military characteristics specified for fixed-wing installation.

g. Discrepancies and Shortcomings.

(1) This paragraph contains discrepancies requiring elimination in order to make the item acceptable for use in the RL-23D on a minimum basis:

| | Discrepancy | Suggested Corrective Action |
|---|---|---|
| (a) | The shear pin in the pitch axis actuator assembly | Modify the AFCS to provide safe reliable disengagement of the |

| | Discrepancy | Suggested Corrective Action |
|---|---|---|
| | shears before fulfilling its design purpose. | pitch axis in event of gear binding or gear jamming. |
| (b) | The TURN knob in the DETENT position is too sensitive. | Decrease the sensitivity of the TURN knob to lateral pressure. |
| (c) | The pilot's view of the navigational-coupler control panel is obstructed by the airplane's control column and the flight controller. | Relocate the navigational-coupler control panel to a more accessible position. |
| (d) | The use of the IN-14 VOR indicator for the HEADING SELECT mode limits the use of the VOR to which the AFCS is coupled. | Install a C-6H radio magnetic indicator (RMI) or a horizontal situation indicator for use with the HEADING SELECT mode. |

(2) This paragraph contains shortcomings which are desired to be corrected in the RL-23D installation as practicable, either concurrently with elimination of discrepancies, or in production engineering, or by product improvement.

| | Shortcoming | Suggested Corrective Action |
|---|---|---|
| (a) | Erratic tracking of the ILS localizer course prior to placing vertical switch in "APPROACH" position and when flying the back course of the ILS localizer outbound. | This condition can be eliminated by placing the vertical switch in the APPROACH position. Instruction manuals should reflect this operating procedure. |

| | Shortcoming | Suggested Corrective Action |
|---|---|---|
| (b) | The use of one indicator light to perform two functions is confusing. | Install a red light on the instrument panel to indicate a.c. or d.c. power failure and use present amber light as the AFCS standby light. |
| (c) | The status of engagement of the vertical and lateral modes can not be determined without observing the position of the switches on the navigational coupler control panel. | Install one amber light for the vertical mode and one amber light for the lateral mode to be activated when the mode is turned off or becomes disengaged. Both lights should be installed on the instrument panel. |
| (d) | The assymetrical power control problem is aggravated when a lateral mode of the navigational coupler is engaged. | Increase the sensitivity of the accelerometer so that it effects rudder displacement in the direction required to maintain the airplane heading. (Replacing a 5-million-ohm calibration card resistor in the yaw actuator with a 100,000-ohm calibration card resistor corrected this condition in the test equipment.) |
| (e) | The word "turn" and the right and left arrows on the TURN knob of the flight controller are not oriented with the movement of the airplane. | Place the word "turn" and the arrows on the forward part of the TURN knob. |
| (f) | The electrical wiring from the flight controller to the airplane's power source and sensor devices of the AFCS | Relocate wiring. |

| Shortcoming | Suggested Corrective Action |
|---|---|
| interferes with the freedom of movement of the pilot's right leg and with the installation of the airplane control lock. | |
| (g) The use of the AN/ASN-13 shock-mounted magnetic compass causes small but constant movement of the rudder pedals. | Provide a directional compass system mounted to the airframe with remote indicator on the instrument panel. |
| (h) No provision exists for limiting abrupt pitch changes resulting from large altitude changes caused by turbulence. | Limit the authority of the AFCS to apply pitch attitude changes to the airplane. |

5. DISCUSSION.

a. Evaluation of the AFCS when coupled to a radar altimeter and Doppler navigation system could not be accomplished because the RL-23D was not equipped with these items.

b. The universal aspects of the AFCS should be thoroughly tested and considered before type classification is recommended. Type classification should be recommended only after completion of the service test of the system in the AO-1 and the H-21.

c. Installation of automatic rudder trim would result in smoother performance of the AFCS in two areas: entry into turns commanded through the TURN knob and operation under assymetrical power conditions. Although it is not required for installation in the RL-23D, it may be mandatory in other types of airplanes in which the AFCS is installed.

6. CONCLUSIONS.

a. The AN/ASW-12(V) Automatic Flight Control System will be suitable for use in RL-23D Airplanes when the discrepancies and shortcomings contained in paragraph 4g are corrected.

b. The AN/ASW-12(V) Automatic Flight Control System appears to be acceptable for use in other Army fixed-wing aircraft.

c. The universal aspects of the AN/ASW-12(V) should be investigated thoroughly before type classification.

7. RECOMMENDATION. It is recommended that type classification action be withheld, pending completion of the service tests of the AN/ASW-12(V) in the AO-1 and the H-21.

8. REFERENCES.

a. Letter, WCOL-9/Capt Norris/29254, US Army Signal Liaison Office, Wright Air Development Center, 4 August 1959, subject: "AN/ASW-12 Meeting."

b. USCONARC-Approved Military Characteristics for Universal Autopilot, 30 September 1959.

c. Subparagraph 533e(11), Combat Developments Objective Guide, DA, revised 31 December 1959.

d. Letter, ATDEV-6 452, Headquarters, USCONARC, 12 April 1960, subject: "Service Test of AN/ASW-12 Autopilot."

e. Letter, 1700-CF.2-8084, Sperry Phoenix Company, 7 July 1960, subject: "L-23D AN/ASW-12(V) Installation," with one inclosure.

f. Letter, SIGRD-5-a-1, OCSigO, 21 July 1960, subject: "Service Test of the AN/ASW-12 Autopilot," with two indorsements.

g. Disposition Form, ATBG-DGAV, US Army Aviation Board, 13 October 1960, subject: "Service Test of the AN/ASW-12 Autopilot," with Comments 2 and 3.

h. Plan of Test, Project Nr AVN 2161, US Army Aviation Board, 4 January 1961.

i. Letter, ATBG-SEC AVN 2161, US Army Aviation Board, 9 March 1961, subject: "Plan of Test, Project Nr AVN 2161, Evaluation of the Automatic Flight Control System AN/ASW-12(V) Installed in an RL-23D Airplane," with one inclosure.

j. Message, ATDEV-6 802196, Headquarters USCONARC.

k. Message, ATBG-DT 3-81, US Army Aviation Board, 30 March 1961.

9. COORDINATION. This report has been coordinated with the US Army Aviation School.

FOR JACK L. MARINELLI
Colonel, Artillery
President